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body would possess, the amount of heat required for the existence of such conditions is not in excess of the supply which we may well suppose to be actually afforded by the planet.

In the case of the outer satellites especially, we can, however, readily conceive that the heating effect of the planet is barely sufficient to overcome the cold of space. The cloud layers are, therefore, in unstable equilibrium, and at any moment some accidental disturbance would determine a general precipitation on the side farthest from the source of heat, thereby reducing the albedo of the satellite from its greatest value, that of pure white clouds, to a much lower one, which would have as its minimum that of the surface of the satellite itself. If at such a time the satellite should be projected on the disc of *Jupiter*, we should have the phenomenon of a dark transit. Such transits would evidently be characterized by an irregularity which is actually a feature of their occurrence.

The brightness of the satellite after it has left the disc is not surprising, when we consider how difficult it is to judge of the relative brightness of two surfaces which are not actually in contact. It is quite likely that a very considerable difference could exist under the circumstances of a transit without attracting notice. It might, however, be detected by careful photometric comparisons immediately after the satellite had passed off the disc.

If the satellites should be found to rotate in such a manner as always to present the same side to *Jupiter*, the explanation here suggested might require modification, although it would not necessarily be false. It will probably be conceded, however, that the evidence of such a law of rotation is at present very slight. J. E. K.

ON THE EXPLANATION OF THE DARK TRANSITS OF *JUPITER'S* SATELLITES.

The recent numbers of the *Publications A. S. P.* have had articles by Messrs. KEELER, BARNARD and HILL on the dark transits of *Jupiter's* satellites. These articles refer both to observations and to possible explanations of the phenomena. It appears to me that the simplest way of accounting for these is somewhat as follows:

The albedo of *Jupiter* is 0.62, and the albedos of the satellites are, respectively: I, 0.22; II, 0.27; III, 0.14; IV, 0.08.

For our purposes we may define

$$\text{albedo} = \frac{\text{light reflected per unit-area}}{\text{light received per unit-area}}.$$

The "light received per unit-area" is the same for *Jupiter* and for the four satellites, and the albedos are proportional to the *mean intrinsic brilliancies* (the average brightness per unit of area), and may be taken as measures of these brilliancies. That is, we may assume the numerical expression of the average intrinsic brilliancies to be 0.62, 0.22, 0.27, 0.14, 0.08 for *Jupiter* and for I, II, III, IV, respectively.

In my view, the whole explanation of the phenomena of bright and of dark transits depends upon the contrast between the brightness of the satellite (*a*, for example) and that of the particular part of the planet upon which it happens to be projected (A, B, C . . . . for example).

Suppose a satellite of intrinsic brightness *a* to approach the limb. It is visible against the sky, because *a* is many times greater than the intrinsic brightness of the sky. It comes to a part of the limb of *Jupiter* where the brightness is A. If *a* is much brighter than A, then the satellite appears bright on a relatively dark background. If $a = \text{A}$, then the satellite is invisible. If *a* is much fainter than A (and if the disc of the satellite is of sufficient angular dimensions in the particular telescope employed), then the satellite appears dark on a bright background. As the satellite successively crosses other regions of the planet, B, C, D, etc., other phenomena arise which are to be explained according to the principles just given.

The angular diameters of the satellites are about—I, 1″.08; II, 0″.91; III, 1″.54; IV, 1″.28; I and II being somewhat the smaller, and, therefore, the least likely to be seen dark on a bright background, on this account alone.

I believe it to be a fact of observation that black transits of II have seldom been recorded; that those of I are comparatively rare; while III, and especially IV, are frequently seen dark in transit. It appears to me that the whole explanation of the matter lies in bringing the foregoing facts together. The explanation has nothing novel about it, as it is essentially that of KLEIN* and of YOUNG.†

I have made an (approximate) determination of the intrinsic brightness of various parts of the disc of *Jupiter* which may have some interest in this connection.

On July 8, 1890, at $13^h\ 3^m$ P. S. T., I took an enlarged picture of *Jupiter*, which was again enlarged, so that the polar axis of the planet was 1.55 inches long. A paper print from this latter negative was cut in two along the polar axis, and the different tints along the line of section were compared with a carefully prepared photographic wedge, lent to me by Mr. BURNHAM, which was graduated into thirteen grades.

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* *Astronomische Nachrichten*, 2014.

† *General Astronomy*, § 624.

The wedge was a photographed paper copy of a drawing in india ink, in which the first grade had one wash of color; the second, two washes; the third, three, etc.*

The darker the paper-print of *Jupiter* (and the graded scale) the brighter was the corresponding area of the planet. Beginning at one pole I matched the paper-print of the planet with the grades of the scale, as follows:

0.00 to 0.09 inches: matches grade 1
0.09 to 0.25 “ “ “ 3
0.25 to 0.33 “ “ “ 6
0.33 to 0.42 “ “ “ 3
0.42 to 0.54 “ “ “ 13 +
0.54 to 0.65 “ “ “ 3
0.65 to 0.87 “ “ “ 5
0.87 to 1.02 “ “ “ 4
1.02 to 1.10 “ “ “ 13 +
1.10 to 1.40 “ “ “ 4
1.40 to 1.55 “ “ “ 1

Leaving out of account all consideration of the errors of the method of comparison and of the errors of the photographic wedge, it follows that the intrinsic brilliancy (photographically) of some portions of *Jupiter's* disc is at least thirteen times as great as the intrinsic brilliancy of the limbs (photographic). It is probably, in fact, even greater than this.

The difference of the *visual* intrinsic brilliancies is by no means so large, but it may safely be said that the brightest parts of *Jupiter's* disc are ten times as bright as the limbs. We know that the satellites of *Jupiter* in transit often appear bright near the limbs, and this will give us an approximate measure of the brightness of the limbs, and hence of the brightness of the most brilliant portions. Taking the numerical expressions of the albedos to be the measures of intrinsic brilliancies, we know that the limbs of Jupiter are sometimes less bright than 0.08 (because Satellite IV sometimes appears bright when it is projected on *Jupiter* near the limbs). Let us suppose the brightness of the limb to be 0.07. Ten times this brightness would be expressed by 0.70. The *average* brightness of *Jupiter* is expressed by 0.62, and hence it is clear that our estimates are not extravagant.

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* It is known that owing to the small "range in sensitiveness" of plates, a wedge so prepared will give equal gradations of light over a small distance only; and that the point of the scale where the grades represent equal gradations is a function of the exposure-time.

From the table above, it follows that much of *Jupiter's* surface is not more than three or four times as bright as the limbs; or, numerically, three or four times 0.07 = 0.21 or 0.28. On a background of brightness 0.21 or 0.28 a satellite of brightness 0.22 (Satellite I) or 0.27 (Satellite II) would usually be lost. There is not sufficient contrast to make it appear either as dark or bright. If, however, any of the satellites chanced to fall on the brightest regions of the planet (brightness = 0.70 or greater), they would certainly appear as dark bodies. I take it, therefore, that the only reason why dark transits of II are not recorded (so far as I know), is because they have not been looked for with the proper instruments and precautions.

The preceding explanation appears to me to account for the facts as well as the meager numerical data will allow, and to have an advantage in that it calls for no assumptions whatever. No collection of past observations of dark transits can throw any material light on the question; but future observations of phenomena of the sort will be of value, if they give numerical estimates of the brightness of the backgrounds on which the satellites are projected.

E. S. H.

NOTE ON THE OPPOSITION OF *MARS*, 1890.

The very severe weather of 1889-90 lasted unusually late into the spring, and the season of excellent nights hardly began before late July or early August. By this time *Mars* was too distant from the earth and too low in the west to be well-observed. All available opportunities were utilized in the early parts of the opposition, and the planet was regularly followed during June, July and August. Experiments were tried with colored glasses, with diminished apertures, etc., all with small success. Many photographs of *Mars* were made, but none of any real excellence.

Drawings of the planet were made on April 3d, 9th, 12th, 26th, 30th, May 3d, 11th, 15th, 18th, 21st, 25th, June 5th, 6th, July 6th, August 5th and 6th. In making these drawings three observers usually took part. E. S. H. and J. E. K. always saw the *canals* as dark, broad, somewhat diffused bands. In bad vision they were drawn in this way by J. M. S. also. Under good conditions, however, the